(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 049 089 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 81304350.2

(22) Date of filing: 22.09.81

(51) Int. Cl.³: B 04 B 1/10, B 04 B 13/00

(30) Priority: 26.09.80 SE 8006732

(43) Date of publication of application: 07.04.82 Bulletin 82/14

(84) Designated Contracting States: DE FR GB IT

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(54) Method and apparatus for monitoring operation of a centrifugal separator.

(57) To monitor operation of a centrifugal separator (21) having a rotor (22) with nozzles (1-16) through which sediment is discharged in jets (26), a sensing means (28) is provided for sensing the respective jets and producing a signal (U) dependent upon the amount of medium in the jets, which signal (U) is supplied to a device (38) which records the signals (U) and is responsive thereto to provide an output indicating a change in the amount of medium in one or more jets, e.g. due to a nozzle becoming blocked or increased in size by erosion, or the mixture supplied to the separator changing.

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Method and Apparatus for Monitoring Operation of a Centrifugal Separator

The invention relates to a method of monitoring operation of a centrifugal separator, and in particular the ejection of separated sediment which is thrown out in jets from the separator rotor through a number of nozzles.

The invention also relates to an apparatus for use in carrying out the method.

A centrifugal separator may have a rotor, which cannot be opened during the operation of the separator and from which sediment is continuously thrown out through a number of nozzles. Alternatively the rotor can be openable during the operation of the separator by moving apart two parts of the rotor, and sediment can be continuously thrown out through nozzles either formed between the parting surfaces of the two rotor parts, e.g. as shown in U.S. Patent No. 4,191,325, or at a distance from the parting surfaces, e.g. as shown in U.S. Patent No. 3,777,972. Furthermore a centrifugal separator can comprise a rotor from which sediment is ejected intermittently through the nozzles which are opened simultaneously during a discharge period while the separator is operating, as described in U.S. Patent No. 4,015,773.

In all the above separators disturbances can occur which depend upon the amount of material thrown

out through the nozzles. For example, a blocked nozzle will cause such a disturbance, which arises because the flow quantity through the nozzle, decreases or ceases entirely due to the blocking. When a nozzle becomes blocked, the sediment which is collected behind the blocked nozzle causes an imbalance of the rotor, creating mechanical stresses which can damage the rotor. These stresses are largest when the rotor passes its critical rotation speeds as it is brought to a stop. The imbalance also increases with time, as the sediment which is located inside a blocked nozzle becomes denser by it gradually releasing lighter liquid phase, which leaves the sediment in direction towards the centre of the rotor.

When a nozzle becomes blocked, the flow of sediment to the adjacent nozzles gradually increases, thereby increasing the risk that these also will become blocked. When two or three adjacent nozzles are blocked, the rotor imbalance is substantially increased.

The sediment which collects behind a blocked nozzle gradually grows inwardly between the conical separating discs of the rotor and can be caught by the lighter liquid phase and carried with it through its outlet from the rotor, the separation thereby being affected adversely.

Hitherto, the blocking of nozzles has been checked by vibration sensing means arranged on the separator to detect an imbalance of the rotor caused by one or more blocked nozzles. Such a vibration sensing means, however, responds only slowly to a blocked nozzle, as a considerable imbalance of the rotor is required before it is detected by the vibration sensing means, and it takes a certain time for the

necessary imbalance to develop after a nozzle has become blocked.

A nozzle which has become enlarged due to erosion by sediment flowing through it will also disturb the separator operation. This disturbance arises through the increased flow through the nozzle. Such an increase in flow means that the concentration of sediment in the jet decreases, which is a drawback since a constant concentration of sediment in the medium leaving sediment outlet of the separator is generally desired.

A change of the flow of mixture of sediment and lighter liquid phase which is supplied to the rotor or a change of the concentration of sediment in the mixture which is supplied to the rotor will also disturb separation operation because the concentration of sediment in the jets will be changed in a way not desired. This disturbance results in a change in the electrical conductivity of the medium in the jets.

An aim of this invention is a method of monitoring operation of a centrifugal separator so that an early indication of a disturbance is obtained and steps can be taken to remedy the cause before any major drawback is suffered.

According to the invention a method of monitoring operation of a centrifugal separator having a rotor with nozzles through which jets of sediment are discharged is characterised by the steps of sensing the jets of sediment and producing a signal dependent upon the amount of medium in the jets and supplying the signal to means responsive thereto for producing an output signal indicating a change in the amount of the medium in one or more jets.

Also provided in accordance with the invention is an apparatus for monitoring operation of a

centrifugal separator by the method, characterised by sensing means, known per se, arranged to sense the sediment jets and produce a signal dependent upon the amount of medium in the jets, and a device coupled to the sensing means and responsive to the signal received therefrom to produce an output indicating a change in the amount of medium in one or more jets.

If the flow in one or more jets ceases or decreases substantially the apparatus will immediately give a signal indicating this condition, and the apparatus according to the invention will react substantially quicker and safer in response to a blocked nozzle than the known vibration sensing means.

It is possible to sum up the magnitude of the signals associated with each nozzle jet and produced during a determined number of revolutions of the rotor and to use the summed up signal magnitudes to determine if the amount of medium in one or more jets has changed. For this purpose the device of the apparatus may be arranged to sum up the magnitude of the signals associated with each nozzle jet during the selected number of revolutions of the rotor and from the summed up signal magnitudes determine if the quantity of medium in one or more jets has changed.

By this it will be possible to use less sensitive sensing means and the influence of noise and the effect of accidental irrelevant signals from the sensing means can be eliminated. For example, a blockage of a nozzle which becomes rapidly cleared will not cause a signal to be emitted by the device.

An output signal may be emitted if the magnitude of the signal associated with one or more of the jets is below a certain value, and in a preferred apparatus the device is arranged to produce

such an output signal.

This is a simple way to determine if certain kinds of disturbances have occurred. The output signal will be obtained when a nozzle has become blocked, the signal will not be produced when a nozzle has become enlarged by erosion.

Alternatively or additionally an output signal may be emitted if the magnitude of the signal associated with one or more of the jets is above a certain value, and the device can be arranged to produce such a signal.

This is a simple way to determine if certain other kinds of disturbances have occurred. The output signal will be obtained when a nozzle has become eroded, but will not be emitted when a nozzle has become blocked.

It is also possible for an output signal to be emitted if the magnitude of a majority of the signals associated with the respective jets is below a certain value, and/or another output signal, if the magnitude of a majority of the signals associated with the respective jets is above a certain value, and the device of the apparatus may be accordingly arranged to produce such signals.

The advantage of such signals is that they make it possible to determine more accurately the cause for the changes in the amounts of medium in the jets.

The jets, which are thrown out from the rotor, can be sensed by different means. According to one embodiment of the invention the sensing means comprises two electrically conducting surfaces, connected in an electric circuit and separated from each other by an electrically insulating surface, the

the jets impinge upon the surfaces and bridge the insulating surface to decrease the resistance of the circuit, and the sensing means emits an electric signal to the device having a magnitude dependent upon the resistance of the circuit.

It has proved that this arrangement can be made very sensitive. The magnitude of the electric signal supplied to the apparatus can easily be increased to increase the current through the circuit. By this the sensitivity of the sensing means can be increased, so that one obtains a sufficiently large electric signal even when media with a low conductivity strikes the sensing means. This arrangement is naturally usable only for electrically conducting media. In practice this does not imply any substantial limitation as most media thrown out from separator rotors have a conductivity which is sufficiently large.

An alternative form of sensing means comprises an element mounted for the respective jets to impinge against and mechanically vibrate the element, a piezo-electric crystal coupled to the element and responsive to the mechanical vibrations to produce an electric signal in the form of voltage pulses with the same frequency as the vibrations of the element.

This arrangement has the advantage of not depending on whether the medium is conductive or not. The sensing means itself is known per se through U.S. Patent No. 4,206,871, where it is used with quite another apparatus, namely for indicating if leakage occurs from a separator rotor.

In another embodiment the sensing means comprises a microphone located in the vicinity of the path of the jets to sense the sound generated by the

respective jet.

A sensing means in the form of a microphone has the advantage that it can be located beside the path of the jets and does not wear under the effect of the jets. The microphone does not need to be located inside the space where the jets are thrown out, but may be located outside this space, possibly abutting against the cover, against the inside of which the sediment is thrown.

Some embodiments of the invention and their operation are described below with reference to the accompanying drawings, in which:-

Figure 1 shows a part cross sectional view of a centrifugal separator equipped with apparatus embodying the invention;

Figure 2 is a sectional view taken along the line II-II in Figure 1;

Figure 3 illustrates an electric voltage of signals produced by the sensing means of the apparatus in Figures 1 and 2;

Figure 4 shows the centrifugal separator and apparatus as Figure 1 and 2 but with an alternative sensing means;

Figure 5 is a sectional view taken along the line V-V in Figure 4;

Figure 6 is a part longitudinal sectional view of another centrifugal separator and apparatus according to the invention;

Figure 7 is a part longitudinal sectional view of a further centrifugal separator fitted with an apparatus embodying the invention; and

Figure 8 shows a signal obtained from an apparatus according to the invention.

With reference to Figure 1 numeral 21 designates a centrifugal separator comprising a rotor 22

with a plurality (sixteen as shown) of nozzles 1, 2, 3... The nozzles have circular cross sections and are evenly distributed around the periphery of the rotor in a common plane perpendicular to the rotor axis 23.

The interior 24 of the rotor is continuously supplied with a fluent mixture of heavier and lighter constituents through supply means (not shown). The heavier constituents, the sediment, are separated from the lighter constituents by action of the centrifugal force and collect in pockets 25, from which it is continuously thrown out through the nozzles in the form of jets 26.

The rotor 22 is enclosed in a cover 27 which collects the sediment thrown out through the nozzles. If one or more nozzles becomes blocked, as illustrated by nozzle 3, heavier constituents accumulate inside the blocked nozzle and the rotor loses its balance with the consequence that its vibration level is considerably increased, which is harmful to the separator.

In order to provide an alarm if a nozzle is blocked, a sensor 28 is inserted in the cover 27. The sensor 28 comprises a central, electrically conducting element 29, which is surrounded by an electrically insulating sleeve element 30, which in its turn is surrounded by a tubular electrically conducting element 31.

The sensor 28 has a smooth end surface 32 formed by the three elements 29, 30 and 31 and to which the element 29 contributes a central, circular, electrically conducting surface 33, the element 30 contributes an annular, electrically insulating surface 34 and the element 31 contributes an annular, electrically conducting surface 35.

The sensor 28 is connected in an electric circuit, which comprises a direct current source 36 and

a resistance 37. Due to the insulating element 30, there is substantially no current in the circuit 28-36-37 when the surface 32 is clean and free from any electrically conductive coating.

The surface 32 is so directed towards the jets 26, that it is hit by the jets in turn as they pass by.

The medium of the jets is presupposed to be electrically conductive. Each time the surface 32 is hit, the medium will bridge the electrically insulating surface 34 and establish contact between the surfaces 33 and 35, with the result that a current flows through the circuit 28-36-37 and the voltage U across the resistance 37 increases and produces a voltage pulse. The more medium that strikes the surface 32, i.e. the larger the flow of medium in the jet, the larger the voltage U of the voltage pulse produced. For a given flow, an increase of the conductivity of the medium will also cause an increase of the voltage U. The voltage pulses are conducted to an apparatus 38, which records the voltage pulses from the hits of the jets on the surface 32 and emits a signal 39 when the voltage U of a voltage pulse is below a certain value. The apparatus 38 can e.g. comprise a counter, which counts the number of voltage pulses which exceed a certain voltage during a given number of revolutions of the rotor and a device which detects when the rotor has rotated the selected number of revolutions. When the number of voltage pulses during the determined number of revolutions is below the number of nozzles which pass the sensor 28 during that number of revolutions, the signal 39 is supplied to an alarm device or to a means to interrupt the operation of the rotor.

One cause for the signal 39 can be

nozzle has become blocked. Another reason for the signal 39 can be a general decrease of the conductivity of the medium leaving the rotor through the nozzles. Such a general decrease of the conductivity can be caused by a disturbance on the inlet side of the rotor, e.g. if the flow of mixture to the rotor has changed or has ceased, or the concentration of sediment in the mixture has changed.

The device for detecting the rotor revolutions comprises a sensing member 40, which senses a permanent magnet 40A fastened to the rotor 22 and emits a pulse for each revolution of the rotor.

When a jet 26 has passed the surface 32, gaseous medium surrounding the rotor 22 blows the surface 32 substantially clean from remaining medium, and the voltage U across the resistance 37 decreasing to a minimum until another jet 26 hits the surface 32 and causes a further voltage pulse.

In Figure 3 is shown how the voltage U over the resistance 37 may vary with time t, when medium from the rotating rotor hits the sensor 28.

At the beginning of a certain revolution, n, of the rotor, the jet 26 from nozzle 1 hits the sensor 28. The nozzle 1 has been eroded by the sediment flowing out through it, so that the flow through the nozzle 1 is larger than the respective flow through the other nozzles. Thus the jet from the nozzle 1 causes a voltage pulse 41, which has a larger maximum voltage than the voltage pulses 42 caused by the jets from the other nozzles. During the next revolution, n + 1, the flows through the respective nozzles have not changed, and the same pulse pattern as during the preceding revolution, n, results.

During the next revolution, n + 2, the nozzle 3 has suddenly become blocked, whereby a voltage

pulse from this nozzle fails to appear on the pulse picture. The pulse picture for the subsequently shown revolutions, n + 3 and n+ 4, shows that the nozzle 3 remains blocked.

The counter of the apparatus 38 counts all the voltage pulses which have a voltage higher than a chosen value U_1. When the number of such voltage pulses goes below the number of nozzles which pass the sensor 28 the apparatus 38 responds and gives off the signal 39. The apparatus 38 can also be arranged such, that it does not give off the signal 39 immediately it receives the first signal from the counter that a voltage pulse has a voltage which is below U_1, but waits until the rotor has rotated a further number of revolutions. Blockage of a nozzle can become cleared soon after it has arisen in which case it is unnecessary for the signal 39 to be produced.

The apparatus is also provided with means, which give off a signal 39A if the voltage of the majority of the voltage pulses 41, 42 is below U_1, and which may comprise a counter, which counts voltage pulses having peak voltage exceeding U_1. When the signal 39A is produced it indicates a disturbance on the inlet side of the rotor, e.g. that the flow of mixture to the rotor has changed or has ceased or that the concentration of sediment in the mixture supplied has changed. If as well the signal 39 the signal 39A is given off, it indicates any of the last mentioned kinds of disturbances may have occurred. If only signal 39 is produced it indicates that one or some nozzles have become blocked.

The apparatus 38 is furthermore provided with means, which give off a signal 39B if the flow of the jets exceeds a certain value corresponding to

a chosen voltage U_2, which is larger than U_1. The signal 39B will be given off when a nozzle has been eroded to a certain degree. Another cause for the signal 39B being given off can be a general increase of the conductivity of the medium which leaves the rotor through the nozzles. Such a general increase of the conductivity can be caused by a disturbance on the inlet side of the rotor, e.g. by the flow of mixture to the rotor having changed or the concentration of sediment in the mixture supplied to the rotor having changed.

The apparatus 38 is also provided with means which give off a signal 39C if the voltage of the majority of the voltage pulses 41, 42 exceeds U_2, and may comprise a counter which counts all voltage pulses having a voltage exceeding U_2. When the signal 39C is given off this indicates a disturbance on the inlet side of the rotor, e.g. that the flow of mixture to the rotor has changed or that the concentration of sediment in the mixture has changed. If as well as the signal 39B the signal 39C is given off, it indicates that any of the last mentioned kinds of disturbances has occurred. If only the signal 39B is given off, it indicates that one or some nozzles have become eroded.

The embodiment according to Figures 4 and 5 differs from the one shown in Figures 1 and 2 only in the sensing means 43, which comprises a disc 44 arranged to be hit by the jets 26, when the rotor rotates in the direction indicated by 45. The disc 44 is fastened to a rod 46, which is elastically mounted in a rubber sleeve 47. When the disc 44 is hit by a jet, the rod 46 is put into mechanical vibration with a particular frequency, and the vibrations are transmitted in the direction of arrow 48 to a piezo-electric crystal

49 arranged at one end of the rod 46. These vibrations are transformed by the crystal 49 into voltage pulses with the same frequency as the vibrations, and the voltage pulses are supplied to the apparatus 38 as a signal that the sensing means 43 has been hit by a jet 26. The larger the force from a jet 26 on the disc 44 is, i.e. the larger the flow in the jet, the larger becomes the signal from the crystal 49 to the apparatus 38. The signals from the crystal 49 have substantially the same appearance as the signals shown in Figure 3 and the apparatus 38 treats them in the same way as in Figures 1 and 2 to establish whether the signals 39, 39A, 39B, or 39C shall be emitted.

In the embodiment shown in Figure 6 the sensing means comprises a microphone 50, which is arranged in the vicinity of the path of the jets 26 and senses the sound energy, which the respective jets produce. The microphone is located behind an annular screen 51, which is hit by the jets 26, and senses through an opening 52 in the cover 27 the sound pulses produced behind the screen 51, inside the sediment collecting space 53, as the jets pass by. These sound pulses are transformed by the microphone 50 into electric pulses, which have substantially the same appearance as, and are treated by the apparatus 38 in the same way, as the pulses in Figure 3 are treated.

The microphone 50 can also be arranged on the outside of the wall of the cover 27 and sense the sound from the jets through the wall. A filter 54 may be provided to filter out low frequency sound from the machine and the surroundings and only let through signals of high frequency to the apparatus 38.

The apparatus according to the invention is

rotor provided with nozzles and openable during operation. Such a rotor 22 is shown in Figure 6. The nozzles 16, 1, 2 are formed in the parting surface 55 between two parts 56 and 57, which during the operation of the rotor are displaceable relative to each other in the direction of the rotor axis to bring the interior 24 of the rotor into communication with the sediment collecting space 53, medium flowing out of the rotor and flushing clean the surfaces, which surround and form the nozzles. Some sediment has a tendency after a nozzle has been blocked to gradually stick to it, so it is important to open the rotor to flush the blockage away as soon as possible after the nozzle has become blocked, which is possible with the apparatus according to the invention.

The apparatus according to the invention is also suitable for use with separators of the kind having a rotor with nozzles which are openable during operation. Such a rotor 22 is shown in Figure 7. The nozzles 1, 2, 3... communicate with respective pockets 25 through axial channels 61 and discharge in the axial direction towards a seat 62. The seats 62 are arranged in a common operating ring 63, which is displaceable towards and away from the nozzles by a motor 64. Figure 7 shows a moment during a discharge period, when all the seats 62 are moved away from the nozzles 1, 2, 3... and the sediment is being thrown out in jets 26. The sediment influences a suitable sensor, e.g. such as that shown in Figures 4 and 5.

The apparatus may be operative only during the discharge periods. This can e.g. be accomplished whereby, simultaneously with activation of the motor 64 to open the nozzles 1, 2, 3..., the apparatus 38 is given a signal to begin to operate.

The apparatus 38 will e.g. give off the

signal 39 if one or more of the nozzles 1, 2, 3... are blocked during the discharge periods.

In Figure 8 is shown how the action of noise, accidental irrelevant signals and blockages which are rapidly cleared can be eliminated by the apparatus 38. The apparatus 38 records for e.g. every 3.6° rotation of the rotor in relation to a fixed angular position, e.g. the position of the sensing means 40, the magnitude of the signal from the sensing means. For each such angular position the magnitudes of the signals are summed up when the rotor 22 rotates e.g. 400 revolutions, a picture of the summed up signal magnitudes V according to Figure 8 being obtained. From a suitable level V_1, it is established if impulses from one or more nozzles have decreased in magnitude. In Figure 8 an impulse from nozzle No. 3 is missing indicating with greatest certainty that it is blocked. From another suitable level V_2, it is established if impulses from one or more nozzles have increased in magnitude. In Figure 8 the impulse from nozzle No. 1 reaches over V_2, indicating that this nozzle has probably become eroded.

The apparatus 38 can be provided with an oscilloscope 71 for showing the pulse pictures shown in Figures 3 and 8. By the permanent magnet 40A taking a fixed position relative to the nozzles, from the oscilloscope picture it is possible to establish which part of the pulse picture belongs to each nozzle. By means of the oscilloscope the condition of the individual nozzles can be observed in it to establish which are blocked or eroded.

From the oscilloscope, when the sensing means shown in Figures 1 and 2 is used, it is also possible to establish if the medium in the jets

generally has changed its conductivity, indicating a disturbance on the inlet side of the rotor, e.g. that the flow of mixture to the rotor has changed.

CLAIMS:

1. A method of monitoring operation of a centrifugal separator (21) having a rotor (22) with nozzles (1, 2, 3 ... 16) through which sediment is discharged in jets (26), characterised by the steps of sensing the jets of sediment and producing a signal (41, 42) dependent upon the amount of medium in the jets and supplying the signal to means (38) responsive thereto for producing an output signal indicating a change in the amount of the medium in one or more jets.

2. A method according to claim 1, wherein during a selected number of revolutions of the rotor (22) the signals associated with each nozzle are summed up, and the summed up signal magnitudes (V) are used to determine if the amount of medium in one or more jets changes.

3. A method according to claim 1 or 2, wherein a signal (39) is emitted by said means (38) if the magnitude (U; V) of the signal (41, 42) associated with one or more of jets (26) is below a certain value (U_1; V_1).

4. A method according to claim 1, 2 or 3, wherein a signal (39B) is produced by said means (38) if the magnitude (U; V) of the signal associated with one or more of the jets (26) is above a certain value (U_2; V_2).

5. A method according to any one of claims 1 to 4, wherein a signal (39A) is produced by said means (38) if the magnitude (U; V) of the majority of the signals

(41, 42) associated with the respective jets is below a certain value (U_1; V_1).

6. A method according to any one of claims 1 to 5, wherein a signal (39C) is produced by said means (38) if the magnitude (U; V) of the majority of the signals (41, 42) associated with the respective jets (26) is above a certain value (U_2; V_2).

7. An apparatus for monitoring the operation of a centrifugal separator (21) by the method of claim 1, the separator including a rotor (22) with nozzles (1, 2, 3...16) through which sediment is discharged through jets (26), and the apparatus being characterised by sensing means (28; 43; 50), known per se, arranged to sense the sediment jets and produce a signal dependent upon the amount of medium in the jets (26), and a device (38) coupled to the sensing means and responsive to the signal received therefrom to produce an output indicating a change in the amount of medium in one or more jets.

8. An apparatus according to claim 7, wherein the device (38) is arranged to sum up the magnitude of the signals associated with each nozzle jet during a selected number of revolutions of the rotor (22) and from the summed up signal magnitudes (V) determines if the amount of medium in one or more jets has changed.

9. An apparatus according to claim 7 or 8, wherein the device (38) is arranged to produce an output signal (39) if the magnitude (U; V) of the signal (41, 42) associated with one or more of the jets (26) is below a certain value (U_1; V_1).

10. An apparatus according to claim 7, 8 or 9, wherein the device (38) is arranged to produce an output signal (39B) if the magnitude (U; V) of the signal (41, 42) associated with one or more of the jets (26) is above a certain value (U_2; V_2).

11. An apparatus according to any one of claims 7 to 10, wherein the device (38) is arranged to produce an output signal (39A) if the magnitude (U; V) of a majority of the signals (41, 42) associated with the respective jets (26) is below a certain value (U_1; V_1).

12. An apparatus according to any one of claims 7 to 11, wherein the device (38) is arranged to produce an output signal (39C) if the magnitude (U; V) of a majority of the signals (41, 42) associated with the respective jets is above a certain value (U_2; V_2).

13. An apparatus according to any of claims 7 to 12, wherein the sensing means (28) comprises two electrically conducting surfaces (33, 35) connected in an electric circuit (28, 36, 37) and separated by an electrically insulating surface (34), the surfaces being so directed towards the nozzles (1 - 16), that the jets (26) impinge upon the surfaces (33, 35) and bridge the surface (34) whereby to decrease the resistance of the circuit, and the sensing means emits an electric signal (41, 42) to the device (38) having a magnitude dependent upon the said resistance of the circuit.

14. An apparatus according to any of claims 7 to 12, wherein the sensing means (43) comprises an element (44, 46) mounted for the respective jets (26) to

impinge against and mechanically vibrate the element, a piezo-electric crystal (49) coupled to the element and responsive to the mechanical vibrations to produce an electric signal in the form of voltage pulses with the same frequency as the vibrations of the element (44, 46).

15. An apparatus according to any of claims 7 to 12, wherein the sensing means comprises a microphone (50) located in the vicinity of the path of the jets to sense the sound generated by the respective jets (26).

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Fig.1

Fig. 2

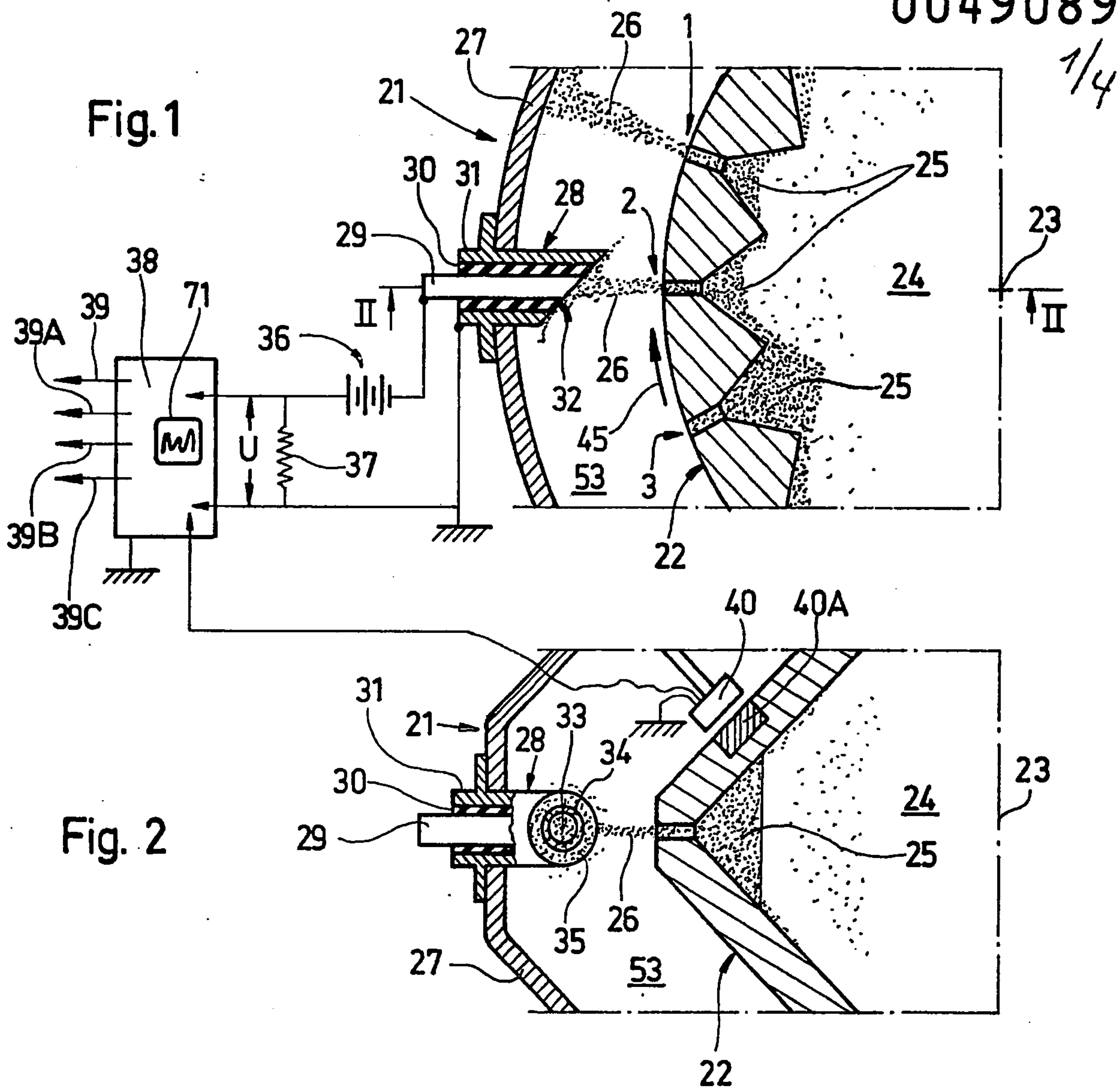


Fig. 3

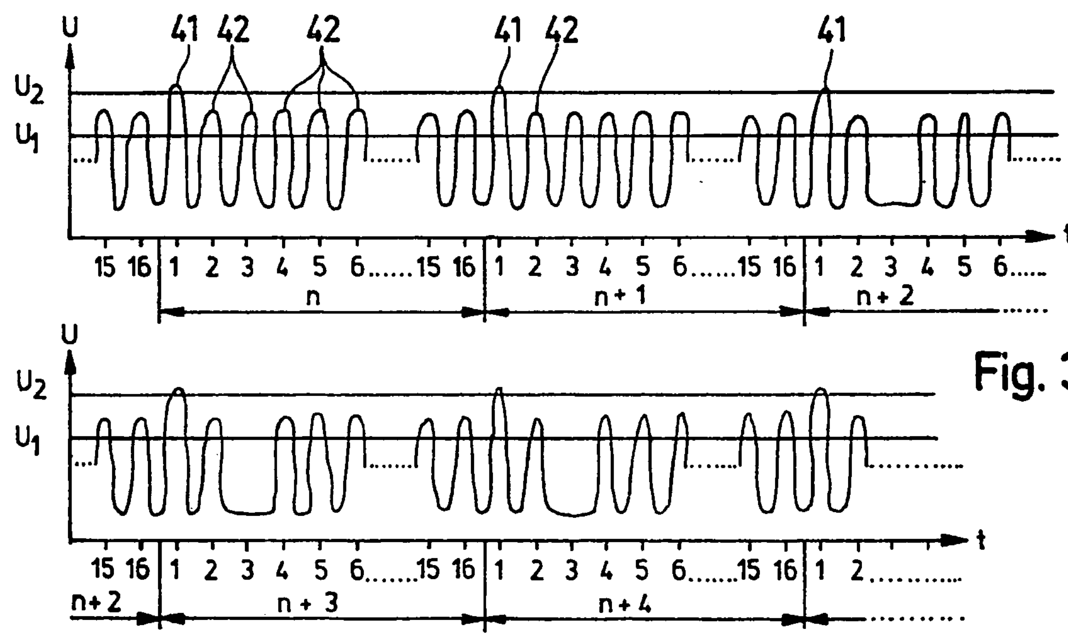
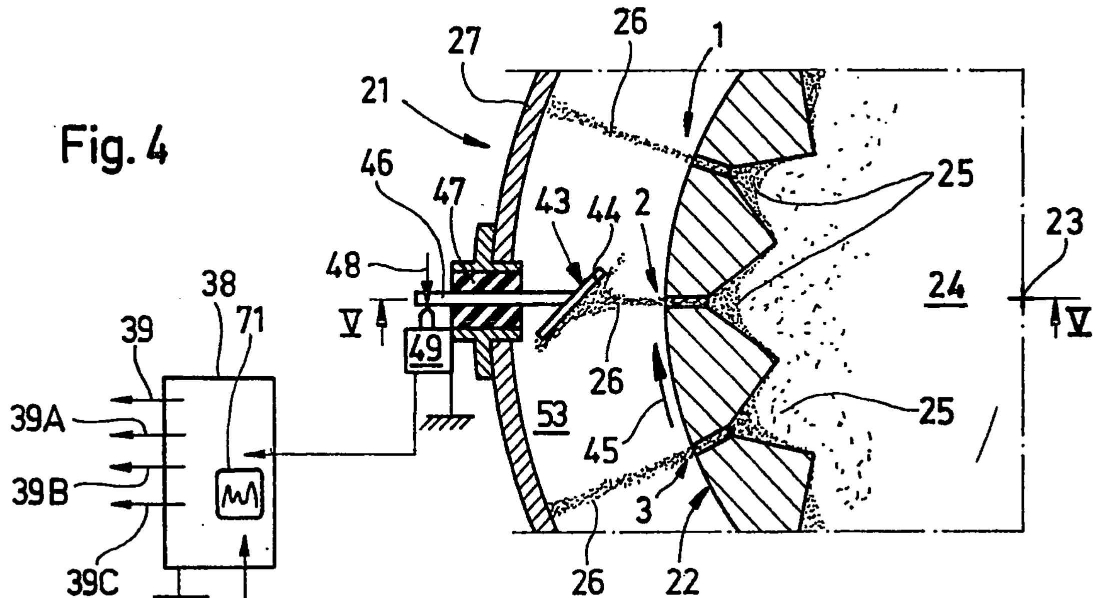


Fig. 4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38
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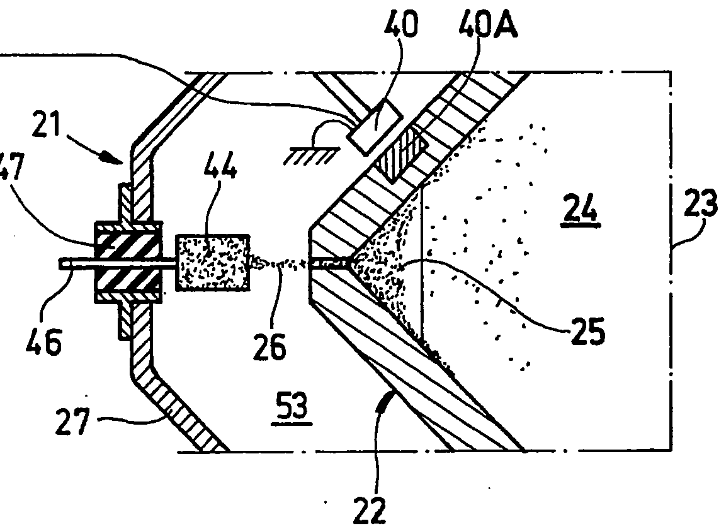
39A
53
45
25
39B
3
39C
26
22

Fig. 5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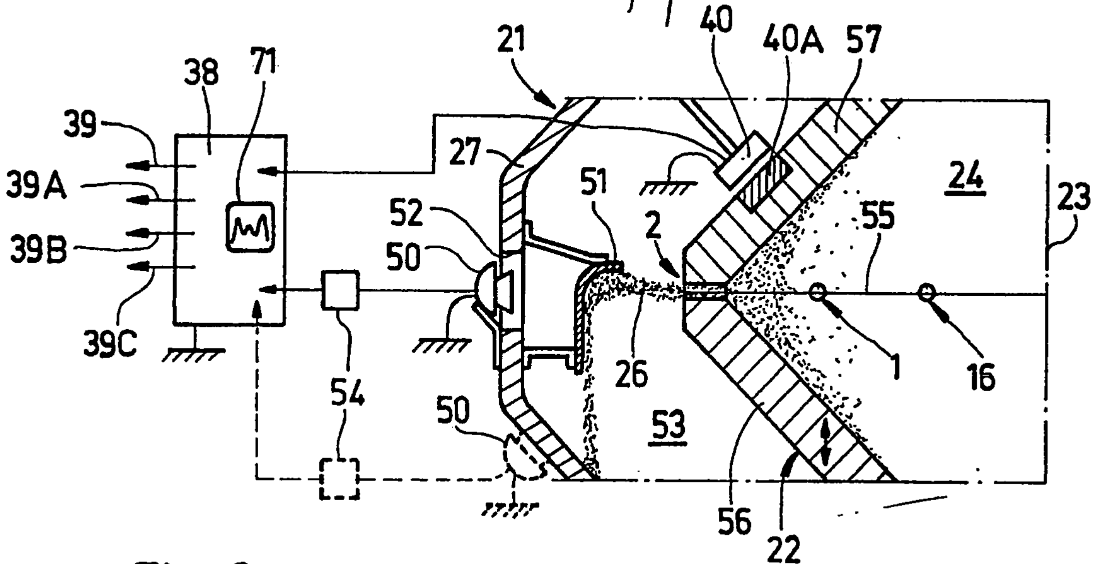

Fig. 6

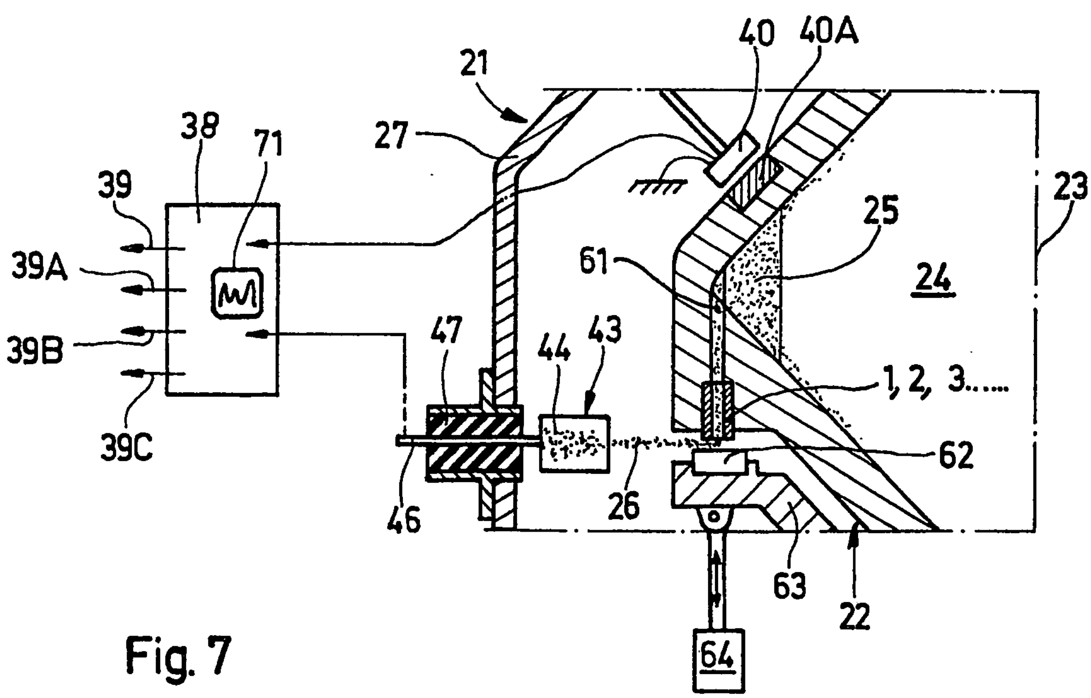

Fig. 7

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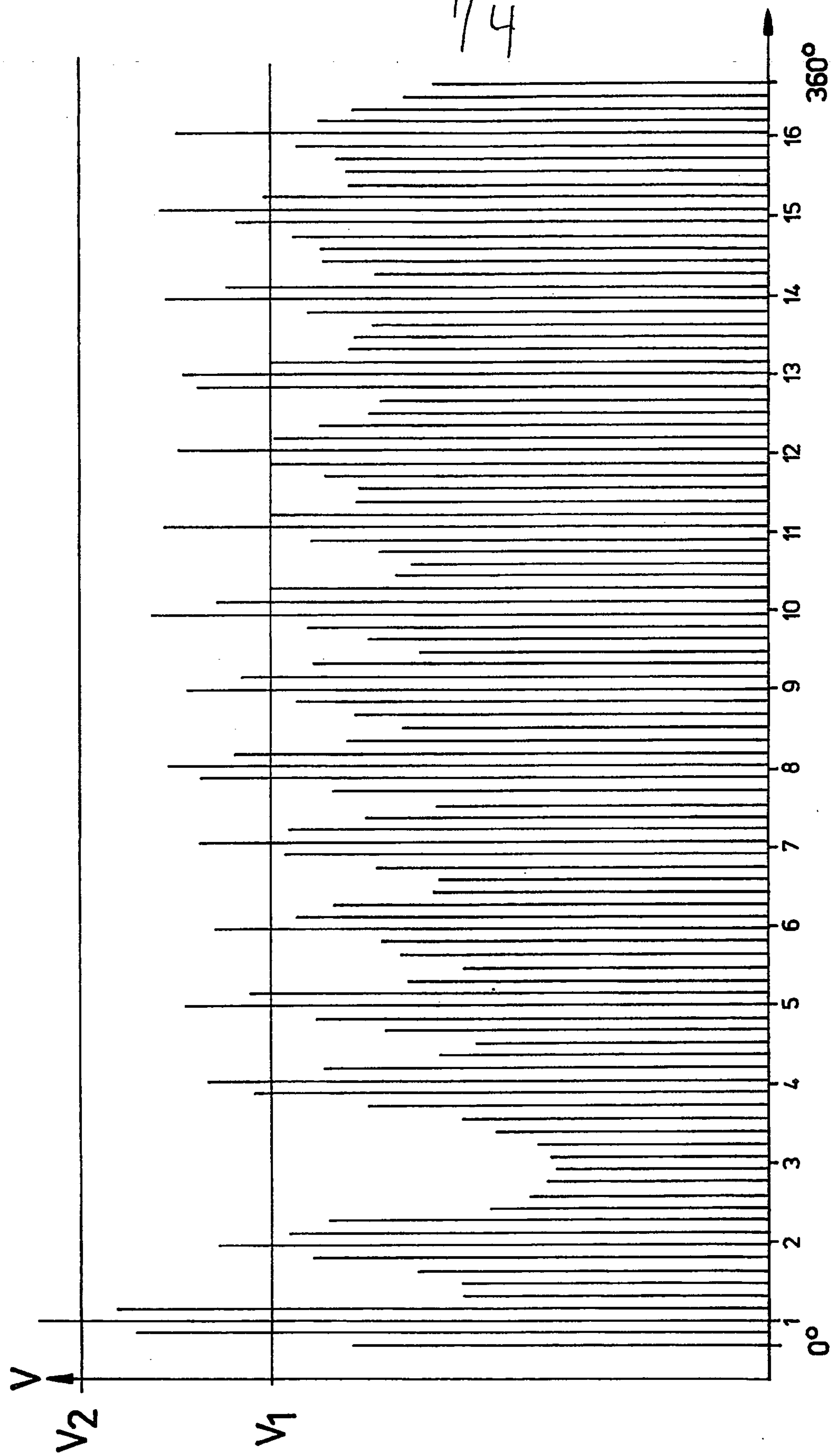

Fig. 8